Chapter 20

Postmortem Skeletal Modification

Bones change as the individual grows. This process, **ontogeny**, continues until late in adulthood in some regions such as the pubic symphysis (see Chapter 18). Because bone is living tissue, it can respond to physical stimuli at any time during an individual's life. Individual variation in any human skeletal element, therefore, can be the result of the bone responding to genetic control, to environmental factors, or to both. The morphological changes discussed in Chapter 18 are **antemortem** effects. They include changes brought about by pathology. After death, however, further changes can occur in bone, brought about by biological, chemical, and physical agencies operating on it. **Postmortem modification** alters both the condition of the individual bones and the completeness of the skeleton as a whole.

The study of the processes that operate between the time of death of the organism and the time of study by the osteologist is called **taphonomy**. Taphonomy, from the Greek words for "burial" and "laws," is a word coined in 1940 by the Russian paleontologist Efremov. Taphonomy is usually described as a subdiscipline of paleontology, but its methods and data are often applied in archaeological and forensic analyses.

Human skeletal remains are recovered from a variety of contexts. These include geological deposits (such as cave floors, alluvial bodies, lacustrine deposits, peat bogs, and volcanic ash), archaeological contexts (such as house floors, wells, battlefields, megalithic structures, plague pits, cemeteries, funeral urns, refuse pits, and even hearths), and forensic settings (such as open-air dump sites, shallow graves, mass graves, or burned structures). Given this variety of contexts, postmortem modification of human skeletal remains can take many forms.

Taphonomy merits the attention of the human osteologist because hominid skeletal remains often bear the traces of past processes and activities useful for inferring past behaviors and events. Human osteologists are often called upon to determine whether the distinctive patterns of damage or element representation (in a skeletal assemblage or an individual) may have resulted from human behavior or natural causes. An understanding of the many processes that alter bones and bone frequencies provides the basis for such interpretations. It is essential that these processes and their effects be understood in order to avoid the mistaken attribution of postmortem modification to antemortem pathological processes (see Chapter 19). In addition to modifying the bones themselves, postmortem processes can dramatically alter the composition of skeletal populations. Several pitfalls of demographic reconstruction involve the differential destruction of skeletal remains due to postmortem processes.

The forensic osteologist working in a crime scene context acts as a member of an investigative team searching for all available clues. However, some physical anthropologists working in archaeological or paleontological contexts have focused exclusively on the retrieval of bones, thereby missing important clues about past behavior. This exclusive focus on the retrieval of

bony specimens has the potential to sacrifice much critical information about the past.

Archaeologists often study burials to understand past cultural activities, particularly mortuary practices. Duday (1978; Duday and Masset, 1987) has consistently called attention to the need for communication between archaeologist and osteologist during every phase of the recovery of skeletal remains. Nawrocki (1995) suggested that this specialized, gap-bridging field of study should be called human taphonomy. It is important to remember that bodies are usually buried, not just the skeletons within them. The disposition of the skeleton therefore provides critical information on how the body was buried. The cultural and taphonomic circumstances surrounding death and the primary burial of the individual both influence the skeleton recovered by the archaeologist. By using all available clues exposed during excavation, the cultural arrangement of the cadaver and the infilling of the burial space may be inferred.

It is most convenient to divide taphonomic agents into two major classes — biological and physical — and to consider human-induced modifications separately. It should be realized, however, that biological agents act to alter human bones through both physical and chemical pathways. This chapter describes and illustrates the effects of the most commonly encountered postmortem alterations of human skeletal remains. The student is referred to Lyman's 1994 volume *Vertebrate Taphonomy* as an excellent extension of much of the subject matter of this chapter, from an archaeological perspective. The same author's *Quantitative Paleozoology* (2008) is an essential companion. Haglund and Sorg's (1997) excellent edited volume *Forensic Taphonomy: The Postmortem Fate of Human Remains* is another valuable resource, as is Section III ("Interpretation of trauma and taphonomy") of Steadman (2003). Chapter 22 considers taphonomic changes to biomolecules. The taphonomy of soft tissues is beyond the scope of this book. A good resource for the study of intentional and unintentional mummification is Aufderheide's (2003) *The scientific study of mummies.* The taphonomy of human hair is discussed by Wilson and Tobin (2010).

20.1 Bone Fracture

In osteological analysis, it is critical to identify deviations of bones from the normal condition and to distinguish between deviations caused by pathological agents and those brought about by taphonomic agents. Assessing bone fracture in an archaeological context is an example of the difficulties of such work. Fracture of a radius, for example, can occur a year before death, an hour before death, immediately after death, or during excavation. The causes of such fracture vary. Antemortem fracture can occur as the individual falls from a tree. Postmortem fracture can be caused by the corpse being forced into a small burial crypt, or by a hyena scavenging the body. Impatient archaeologists also have been known to fracture bones through carelessness. Signs of bony healing around the fracture could identify the fracture as antemortem. Without this healing, however, the osteologist may be forced to identify the fracture as **perimortem** (around the time of death), implying that it is not possible to ascertain whether the fracture occurred just before, during, or after death. Ubelaker (1992b) notes the significance of fracture of the hyoid in a forensic context. Death by strangulation sometimes involves hyoid fracture. However, dissection during autopsy can also fracture the hyoid. Incomplete ankylosis of the horns to the body of the hyoid is sometimes mistaken for fracture. The hyoid can be fractured prior to death and not show significant remodeling at the time of death. The osteologist's most important contribution to a forensic investigation may be to bring all these possibilities to the attention of the investigative team.

The rate at which a bone loses its organic component and becomes "dry" as opposed to "green" or "fresh" varies widely, depending on the environment of deposition. Mineralization or "fossilization" of the bone also depends more on context than on elapsed time. Despite the variations in rate of change, it is often possible to distinguish between ancient (perimortem) fracture of bones that still retained much organic component when broken, and recent (postmortem) fractures of dry bones that occurred during excavation and transport. Discrimination is often facilitated by

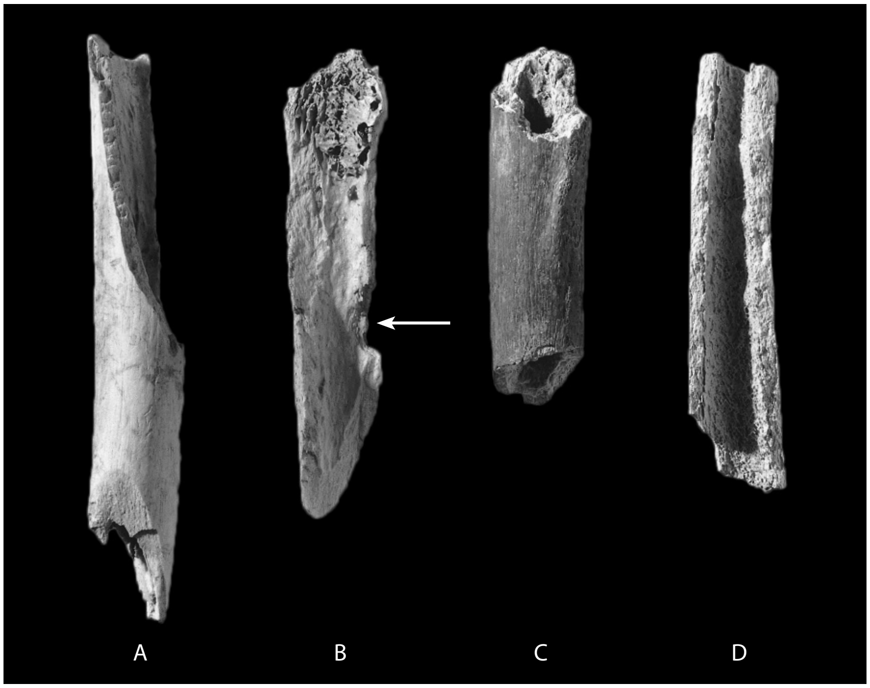


Figure 20.1 **Recent versus ancient fractures.** Ancient perimortem (A, B) and recent postmortem (C, D) fractures of human femoral shafts. Specimens A and B are from an archaeological context in which the bone was fragmented when fresh, whereas specimens C and D were fractured during retrieval of the elements from the ground. Note the conchoidal impact scar on the internal surface of specimen B (*arrow*). One-half natural size.

reference to the surface color and edge characteristics of the broken surfaces (Figure 20.1). Ancient longitudinal or spiral fractures of the shaft are usually straight, with sharp, linear edges. Because the fracture surface had already formed at the time of burial, this surface is usually the same color as the rest of the bone surface. However, dry or fossilized bones that have been recently broken usually have rougher, more jagged fractures, and the fracture surface is usually a different color (lighter in most unfossilized bone) than the adjacent unbroken surfaces. See Section 19.2.1 for more information on the various kinds of antemortem and perimortem fractures.

As described in Chapters 4–14 and 19, individual bones perform different mechanical and physiological functions. These functions are reflected in the wide variation in size, shape, density, and internal structure of the bones. These characteristics, in turn, affect the potential for postmortem fracture of each element and even parts of elements. For example, human femoral shafts from archaeological collections are far more likely to escape the ravages of biological and physical destruction than the smaller, more fragile sternum. Element representation in excavated skeletal assemblages can therefore be altered significantly from that predicted by element ratios in the intact skeleton. The absence of hand phalanges in an excavated cemetery assemblage usually does not mean that bodies were buried without fingers. Instead, such absence more often indicates that years of postburial rodent tunneling through the site displaced these small elements, or that recovery techniques were not adequate. Imaginative attribution of the disproportion to some ritual activity involving removal of the fingers would be unwarranted in such a case.

The appreciation that patterns of element disproportions in the archaeological record are not all attributable to human intervention has caused archaeologists to look closely at natural bone modification in the modern world. These **actualistic** studies have shown repeatedly that the structure of the bones themselves is often a major determinant of patterning in the archaeological record. For example, the edge of the tibial plateau is often eroded simply because of its prominence and thin cortex, whereas the shaft of this element is rarely damaged.

20.2 Bone Modification by Physical Agents

20.2.1 Chemistry

Postmortem changes in bone range from minor alterations of bone proteins to complete structural and chemical breakdown. As outlined in Chapter 3, the major constituents of bone are protein (mostly collagen) and minerals. The relationship between these constituents involves complex structural features and chemical bonds whose nature is not fully understood (Collins et al., 2000; Nielsen-Marsh et al., 2000; Collins et al., 2002; Denys, 2002; Hedges, 2002; Forbes, 2008). When the organism dies, the once-dynamic bone tissue begins to disintegrate. Soil acidity (pH) and permeability, moisture, temperature, and microorganisms can all dramatically affect the rate of skeletal deterioration. Depositional environments such as the dry Egyptian or Peruvian deserts, and the cold, dry arctic can even preserve soft tissues. Other depositional conditions ensure destruction of even the teeth. Differences in soil conditions, even within a single burial, can result in differential destruction. In general, better bone preservation is present in well-drained areas with low water tables, in soils with a neutral or slightly alkaline pH, in temperate areas,

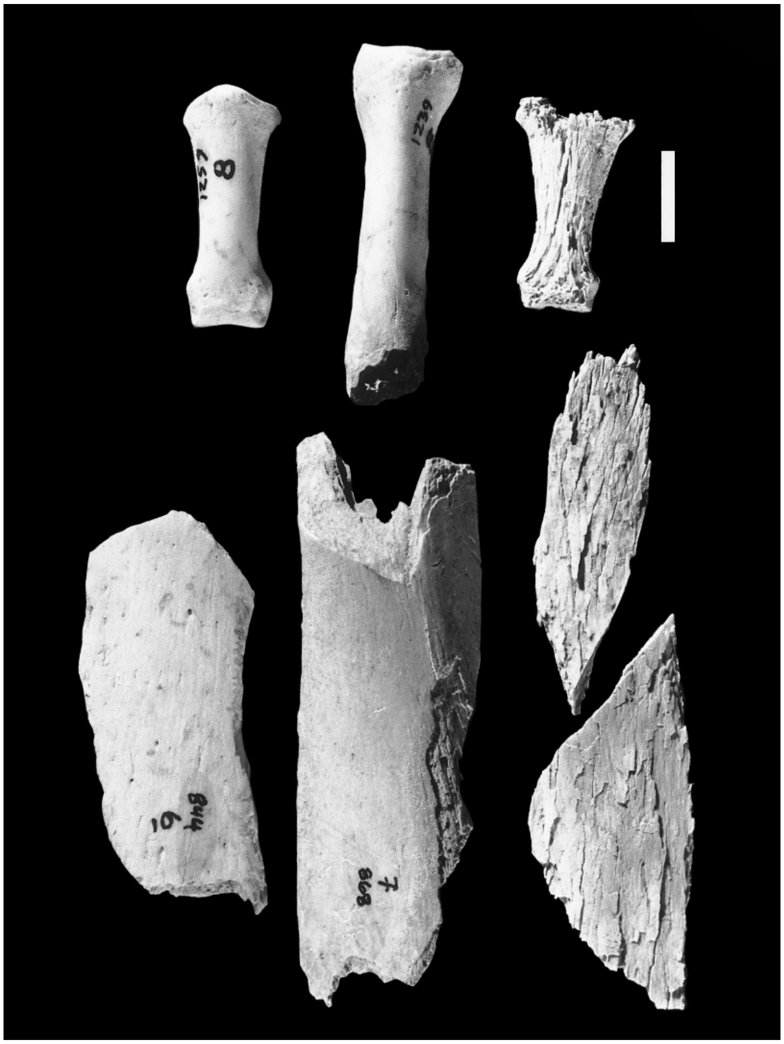


Figure 20.2 **Burning and weathering of bone.** The shaft fragments and phalanx on the right show characteristic cracking, degreasing, and exfoliation associated with weathering. These human bones lay exposed on an unprotected surface in Colorado for about 15 years. The femoral shaft fragment and phalanx in the middle show bone deterioration, discoloration, and exfoliation indicative of damage by burning. Note that the contact between damaged and undamaged surfaces is abrupt. Soft tissue protects the deeper bones, whereas subcutaneous bones or bone portions is more susceptible to such damage when fleshed bones are burned, so the pattern of damage provides clues to the amount of soft tissue on the body when burning occurs. The limb-bone shaft splinter and phalanx on the left are unaltered. Bar: 1 cm.

and in deeper burials (Henderson, 1987; Janaway et al., 2009). These generalizations are often violated, however, because preservation is so dependent on unique combinations of these variables in local depositional settings. The color and degree of fossilization are also controlled by the environment of deposition. Under the right conditions, a bone can become completely fossilized in a few thousand years.

When unfossilized bone is exposed to the elements, particularly rain and sun, its surface deteriorates at the same time that its organic content is lost. Weathering bones first display a network of fine, usually parallel surface cracks. These cracks progressively deepen and widen as the bone surface begins to deteriorate (Figure 20.2). The rate of weathering depends on temperature and humidity, but archaeologists have attempted to use bone weathering to estimate how much time some bone assemblages took to accumulate on former land surfaces (*e.g.,* Behrensmeyer, 1978; Todisco and Monchot, 2008), and forensic osteologists use similar observations (*e.g.,* Janjua and Rogers, 2008; Ross and Cunningham, in press). Lyman and Fox (1997) discuss the pros and cons of weathering data in both realms.

20.2.2 Rock, Earth, and Ice

Bones on the surface of caves can be broken and scratched by rockfall. Buried bones can be fractured by earth movement. In colder climates, the freeze-thaw cycle can result in damage to bones. The postmortem alteration caused by these nonhuman physical agencies may include striations and polishing that might be attributed to human intervention. However, in such circumstances the depositional context and configuration of damage can provide important clues for the accurate interpretation of the bone modifications. Tersigni (2007) reviews the effects of freezing on human bone.

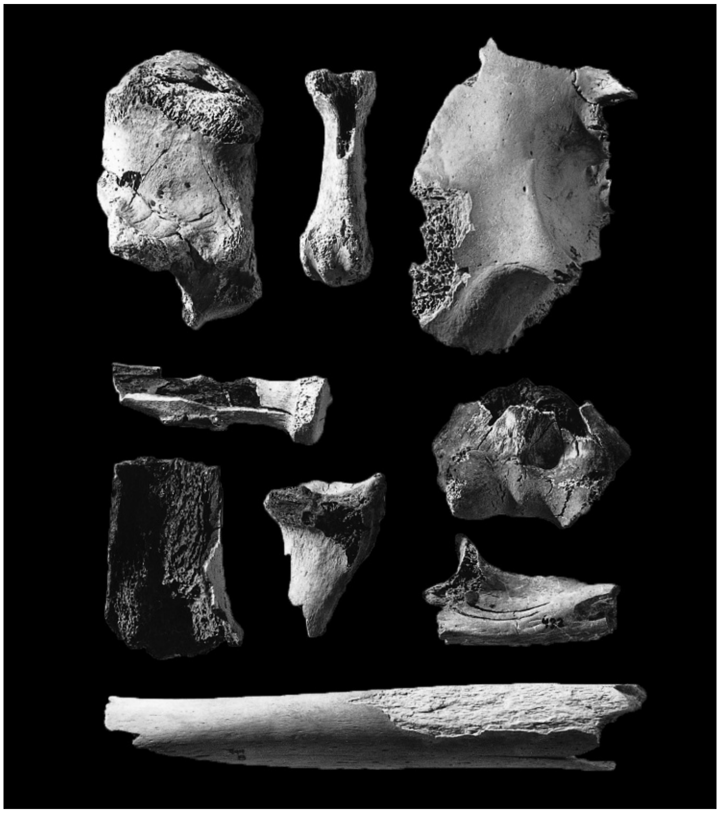


Figure 20.3 **Burned human bone.** Burning here has resulted in splitting, cracking, and discoloration of the specimens, exfoliation of the cranial vault bone (*upper right corner*), and destruction of the subcutaneous surface of the tibial shaft fragment (*bottom*). One-half natural size.

20.2.3 Abrasion

Particles of grit suspended in aerial or aqueous environments can abrade bones, reducing surface relief. Such sandblasting effects are commonly observed in bones exposed on the surface in desert conditions or transported in a river. Many fossil assemblages are recovered from fluviatile environments and their elements often show abrasion damage.

20.2.4 Fire

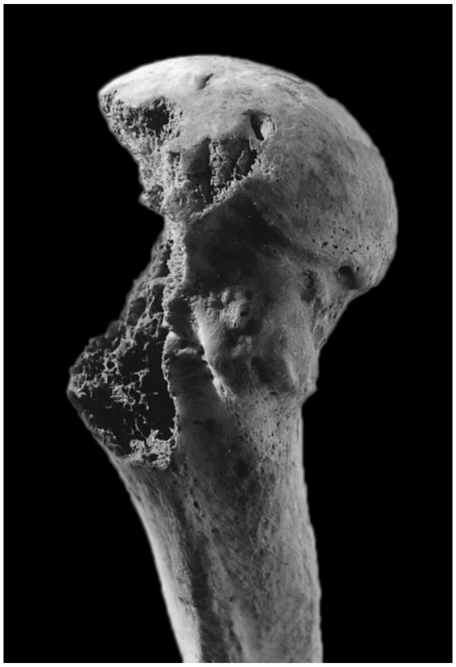
It is possible for bones to become charred by naturally occurring fires, but the effects are usually not as severe as damage caused by mortuary (cremation) or dietary (roasting) practices (Figures 20.2 and 20.3). For many archaeologists and osteologists, an introduction to cremated human bone is the first encounter with burned bones. This is unfortunate because the objective of cremation as a mortuary practice is the destruction of the body. Cremated bones are typically heated to very high temperatures and characteristic color changes and cracking accompanies the loss of the organic portion of the bone tissue. It is necessary to recognize, however, that bone subjected to lower temperatures for shorter periods of time is not so conspicuously altered. In fact, burning of bone tissue may so closely mimic normal bone-weathering processes that microscopic or chemical analysis is necessary to distinguish the two (Taylor et al., 1995). Burning (charring) of bone tissue is also sometimes confused with staining (particularly manganese staining) of bones in some depositional contexts (Shahack-Gross et al., 1997). When analyzing evidence for the burning of human bones, the osteologist should always be attentive to the depth and character of the soft tissue that covered the particular osteological element at death. The molar enamel, for example, is exfoliated less frequently than incisor enamel because when the head is exposed to fire the incisors are exposed to very high temperature, whereas molars are more protected because of coverage by more soft tissue. Pijoan et al. (2007) provide a review of thermal alterations in archaeological bones, and Schmidt and Symes (2008) provide a book on the topic.

20.3 Bone Modification by Nonhuman Biological Agents

20.3.1 Nonhuman Animals

Carnivores such as hyenas, wolves, dogs, leopards, vultures, crocodiles, and even insects can have a dramatic impact on bones and bone assemblages. These animals, particularly the canids and hyenids, are agents of bone destruction because they break bones between their teeth in an effort to retrieve the fat and marrow within. The soft, trabecular portions of bones are favored by these animals, and even a small hyena is fully capable of splintering the shaft of an adult human femur. Carnivore damage to bones is recognized by the signature of the teeth—pitting, scoring, and puncturing of the bone surface (Figure 20.4). Haglund et al. (1988) provide a brief account of forensic cases in which human skeletal remains were ravaged by carnivores. Haglund (1997) reviews canid data. Njau and Blumenschine (2006) report results of crocodile feeding experiments. Haglund (1992) contrasts rodent and carnivore damage, and Faith et al. (2007) consider how carnivore competition and bone density can affect bone destruction in the wild.

Although rodents are generally smaller than carnivores, their gnawing can be just as destructive. Rodents ranging in size from mice to large porcupines chew on bones. Like carnivores, large rodents can move bones around on the landscape, often carrying them over large distances to their dens, where they accumulate and modify them by chewing. The chisel edge of the rodent incisor is used to shave away the surface bone, producing a distinctive, fan-shaped pattern of regular, shallow, parallel or subparallel, flat-bottomed grooves that are usually concentrated on the projecting surfaces of bones. These traces can be patterned and regular (Figure 20.5), but they should not be confused with modifications to bone made by humans. Klippel and Synstelien (2007) review



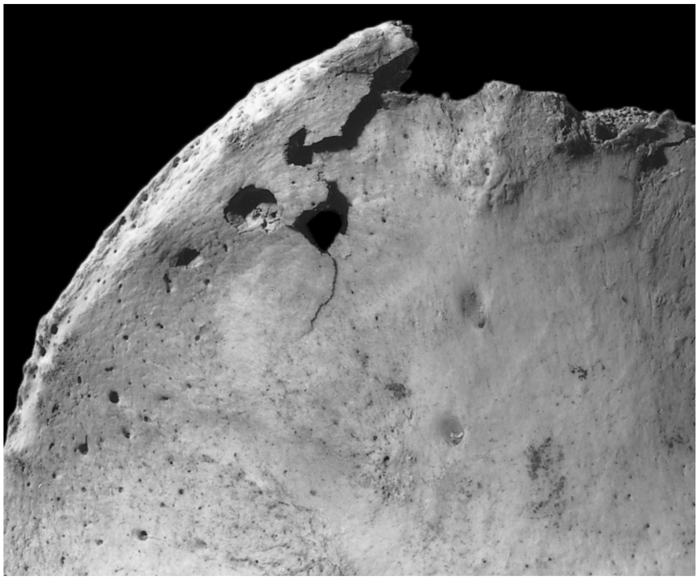


Figure 20.4 **Carnivore-gnawing marks on prehistoric human skeletal elements.** The femur (*top left*) shows destruction of the spongy bone of the greater trochanter and associated broad horizontal grooves made by carnivore teeth just below the trochanter position. The humerus (*top right*) shows similar destruction of trabecular bone along with small punctures left by gnawing on the articular surface of the head. The os coxae (*bottom*) shows destruction of the iliac crest and adjacent perforations caused by gnawing. California. Natural size.

rodent gnawing and Reeves (2009) considers the effects of vultures.

In addition to displaying traces of chewing by mammals, bones can be scarred by the action of mammalian feet. Trampling by ungulates and polishing by constant passage of carnivores in a lair may scratch and polish bone surfaces. The superficial striations that result from trampling might be mistaken for cut marks until it is appreciated that these marks, unlike cut marks, are usually randomly oriented and concentrated in fields of parallel striae across the most prominent parts of the bone.

Insects can also damage bones. Huchet et al. (in press) discuss the effect of termite grawing on archaeological human remains, and Kaiser (2000) describes pre-depositional insect damage to fossil bones from the hominid site of Laetoli, Tanzania.

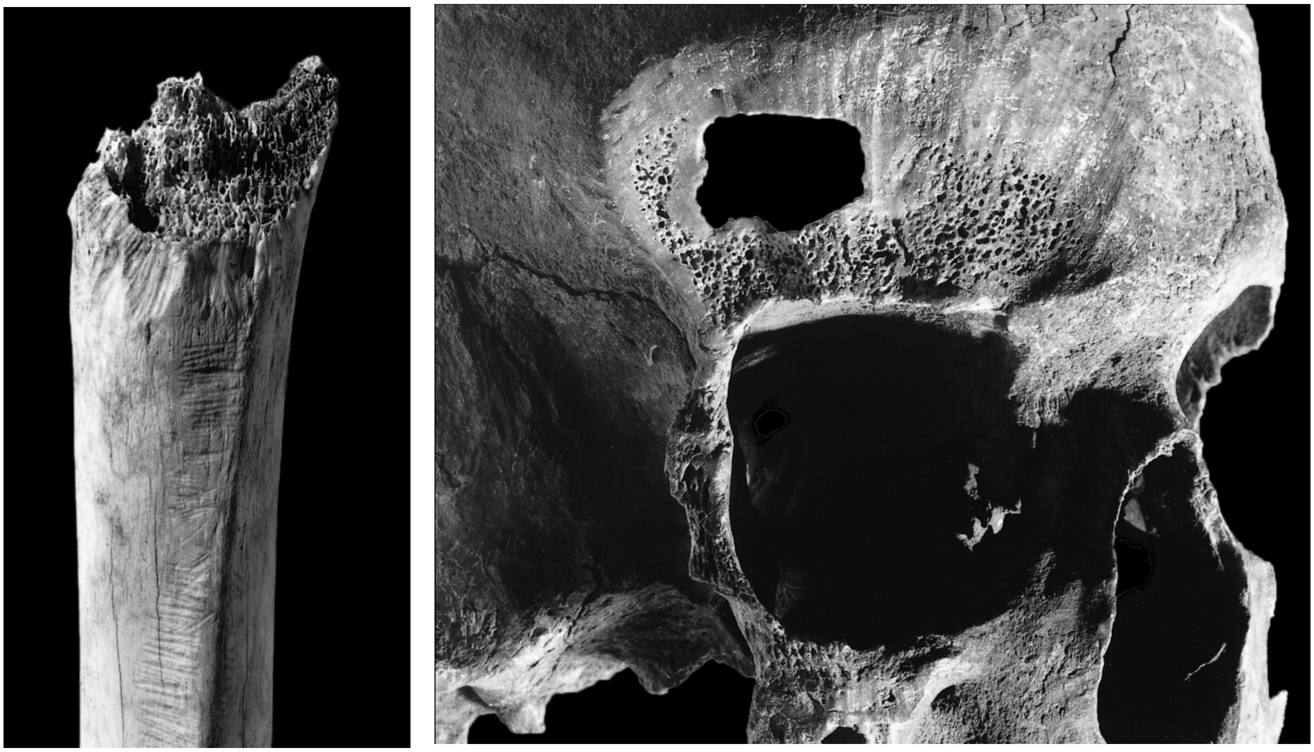


Figure 20.5 **Highly patterned rodent gnawing marks on human skeletal elements.** The tibia (*left*), from prehistoric California, shows gnawing by a very small rodent. The cranium (*right*), from a prehistoric African site, shows heavy gnawing, with broader gouges left by the incisors of an African porcupine. Natural size.

20.3.2 Plants

Plants send their roots into the ground in search of water and nutrients. These roots secrete acids that can be very effective at etching the surfaces of buried bones. The initial pattern of root damage is usually a reticulate network of shallow grooves that should not be mistaken for the work of prehistoric engravers (Figure 20.6). This root-etched network can become so dense that the entire outer surface of a bone is etched away. Individual root-mark grooves are often whiter in color than the surrounding bone because of decalcification brought about by the acid.

20.4 Bone Modification by Humans

Distinguishing human from nonhuman agents in the modification of skeletal remains continues to preoccupy anthropologists studying human origins in Africa, the peopling of the New World, and many other problems of prehistory. As noted previously, many actualistic studies have been conducted with the goal of discovering diagnostic attributes of human bone modification in archaeological contexts. Most of these studies focus on nonhuman skeletal remains and are referred to as **zooarchaeology**. Their results also apply in cases where human remains are the objects of human modification.

Human mortuary practices may have profound effects on the disposition of a skeleton. For example, the forcing of the corpse into a small space can cause strange anatomical juxtapositions and even fractures. In secondary burials, there are often traces of human activity left on the bones; defleshing can leave cut marks and scraping marks on the bones, and cremation usu-

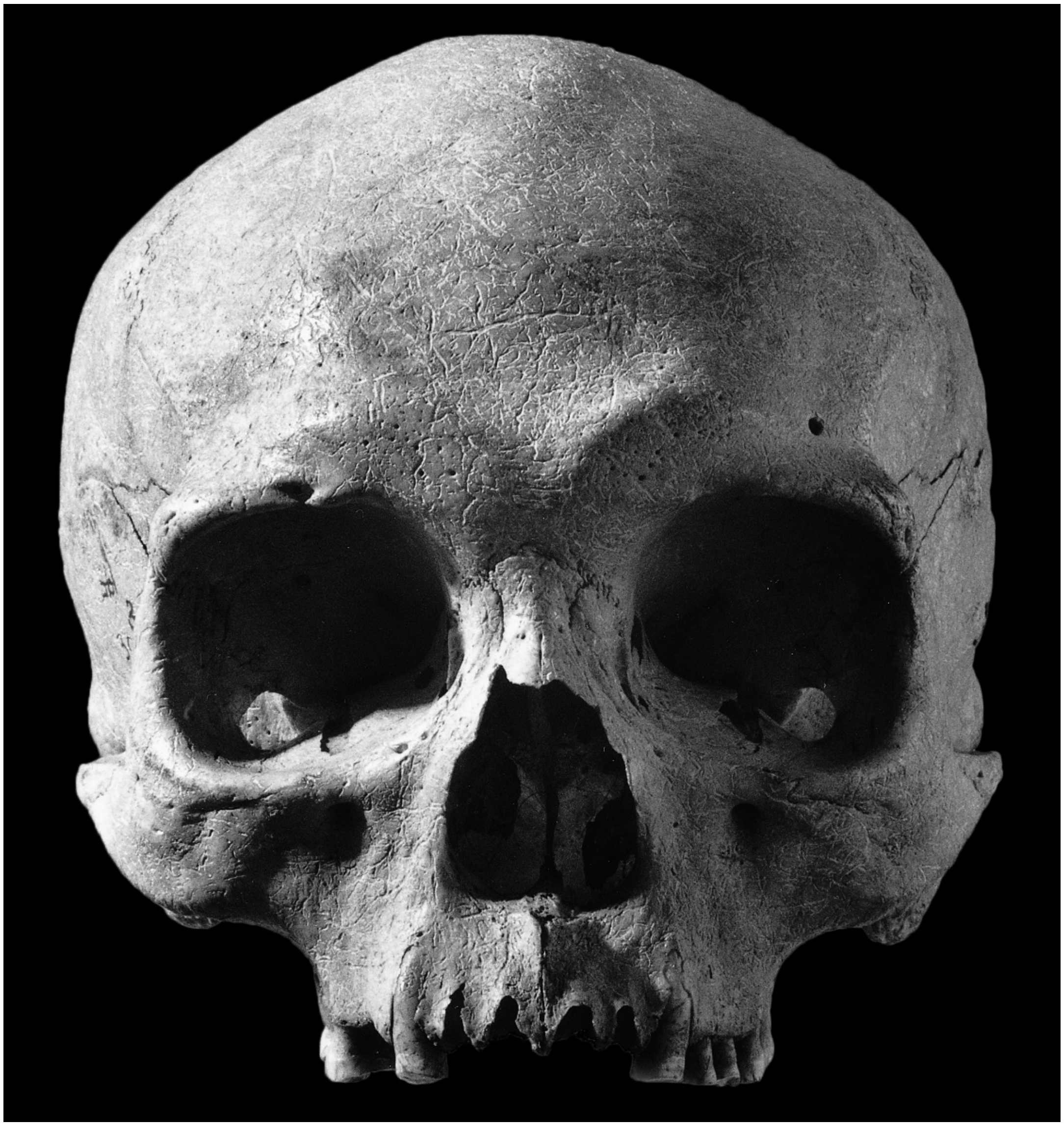


Figure 20.6 **Root marking on a human cranium from a prehistoric California site.** Such delicate, intricate etching of grooves should not be mistaken for cultural activities. Natural size.

ally causes charring (resulting in white, gray, black, and blue hues) and transverse cracking of the bones. Fortunately for the osteologist, aboriginal cremation may be inefficient, leaving identifiable fragments available for recovery and analysis.

Cannibalism in an archaeological context is a topic of considerable anthropological interest. Humans can fracture long-bone shafts with hammerstones and pulverize long-bone ends to extract nutritious fat. Percussion pits and anvil scars are usually seen under these conditions (see Chapter 26; White, 1992; Turner and Turner, 1999). Cut marks made by stone or metal tools may also appear on skeletal remains in a cannibalized assemblage (Rautman and Fenton, 2005). Burning of the bone associated with roasting is often concentrated on the subcutaneous surfaces of bones such as the cranium, mandible, and tibia. Processing of bones by cooking at lower temperatures generally leaves no obvious signature, but such cooked bones can be identified using transmission electron microscopy (Koon et al., 2003). Study of the patterns of bone destruction

through bone assemblage composition and the actual physical traces left on individual bones often makes it possible to distinguish between human and nonhuman damage to bones.

As noted in Chapters 15 and 16, improper excavation, transport, and cleaning of bones in the field or laboratory can result in damage to skeletal remains. This "preparation," or cleaning, damage is usually easily discernible from perimortem damage on the basis of its distribution and surface characteristics. Many of the world's most famous hominid fossils have been damaged in this manner. Metal instruments, including dental picks, electric drills, and even wire brushes, can all leave traces on osteological specimens, but this damage should never be mistaken as evidence for prehistoric human behavior. The osteologist should take precautions to avoid inflicting such damage on skeletal remains. These excavation- and preparation-related defects are often easily diagnosed based on their color. Ancient surficial defects in a bone usually accumulate soil, matrix, stains, or other residues that darken them relative to the adjacent bone. Recently made defects are usually lighter in color and free of staining and microscopic and macroscopic foreign debris.

Discrimination between taphonomic agents or "agencies" that anciently caused surface modifications to bones is often thought to be a more difficult task. For example, some have advocated the use of scanning electron microscopy to choose between diagnoses of carnivore chewing marks or humanly induced cut marks. Blind tests in a study by Blumenschine et al. (1996) demonstrated inter-analyst agreement and accuracy in identifying cut marks, percussion marks, and carnivore tooth marks, approaching 100% for experts. Major human-made modifications to bone surfaces are outlined in the following sections and are illustrated and discussed by White (1992).

20.4.1 Cut Marks, Chop Marks, and Scrape Marks

When the sharp, often irregular edge of a stone tool contacts the surface of a bone during defleshing or disarticulation activities, a **cut mark** (Figure 20.7) is formed. These marks are usually much narrower, finer, and more V-shaped than carnivore tooth marks. Unlike the single rough furrow of a carnivore mark or the flat-bottomed trough of a rodent incisor mark, cut marks usually display striae within the mark and often show "shoulder marks" or "barbs" where different parts of the tool edge contact the bone and thereby cut their own parallel or subparallel marks. However, the ridges and crenulations on crocodile teeth may mimic this microdamage (Njau and Blumenschine, 2006, contra McPherron et al., 2010). Cut marks are usually the result of slicing activities in which the blade of the tool is used perpendicular to the grain of the tissue being sliced. **Chop marks** (Figure 20.8) are similar to cut marks, but result from forceful and abrupt contact between tool edge and bone rather than from slicing activities. Chop marks are less frequent in archaeological bone assemblages modified by stone tools with fragile edges and are more frequent in forensic cases where metal implements allow the chopping of tissues (Alunni-Perret et al., 2005). **Scrape marks**, made when the edge of the tool is scraped across the surface of the bone, also show lower frequencies in archaeological assemblages for the same reason. These are usually shallower than either cut marks or chop marks, but they cover wider areas with many parallel or subparallel striations.

20.4.2 Percussion Marks

Cut marks and chop marks are encountered in both forensic and archaeological contexts. In the forensic context, such marks can indicate antemortem trauma or postmortem attempts to disarticulate body segments. Once disarticulated and (less frequently) defleshed, the elements of the skeleton can be reduced further by direct percussion with a heavy object. This is rarely seen in forensic contexts, but it is virtually universal in zooarchaeological contexts. Fat is highly prized by many people, and bones contain fatty marrow in both their medullary cavities and their trabecular regions. To obtain fat from the first location, the shafts are cracked and pulled apart. Fat in the spongy bone can be extracted by eating the crushed trabecular portions or by boiling them to

Figure 20.7 **Cut marks made by stone tools on two femoral shaft fragments and a clavicle.** Cut marks are usually patterned with respect to the soft tissue that was being cut from the body — here, defleshing cut marks to remove leg musculature, and marks made in the process of decapitation. Bar: 1 cm. From White (1992).

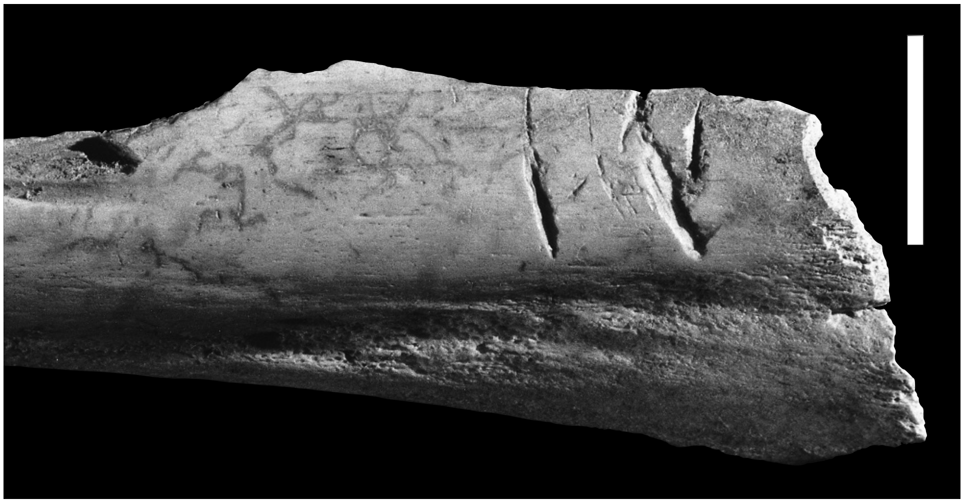


Figure 20.8 **Chop marks made by stone tools on the posterior surface of a proximal tibial fragment.** Bar: 1 cm. From White (1992).

render the fat in cooking vessels. All of these cultural activities have the potential to leave traces on the bones, and all have been investigated actualistically (White, 1992; Pickering and Egland, 2006).

When fracture of the bone is effected with a stone hammerstone, irregular, roughened **percussion pits** (Figure 20.9) that correspond to the tip of the percussor may be left on the bone (particularly if all soft tissue has been removed). If this activity is undertaken on an anvil or if the percussor moves slightly as it impacts the bone, **percussion** (or **anvil**) **striae** (Figure 20.10) may result. This activity often produces **inner conchoidal scars** (Figure 20.11) on the medullary cavity surface of the bone shaft and **adhering flakes** on the shaft wall. When the target marrow is in the trabecular portions of the bone, the percussion to this area sometimes creates crushing (Figure 20.12), and when fresh bone fragments are pulled apart forcefully, the result is sometimes peeling, particularly on immature bones and ribs (Figure 20.13). When the fragmented bones are boiled in ceramic vessels in an attempt to render grease, some of the shaft fragments may acquire a peculiar form of abrasion on their tips called **pot polish** (White, 1992).

Figure 20.9 **Percussion pits**. Made by stone hammerstones. Bar: 1 cm. From White (1992).

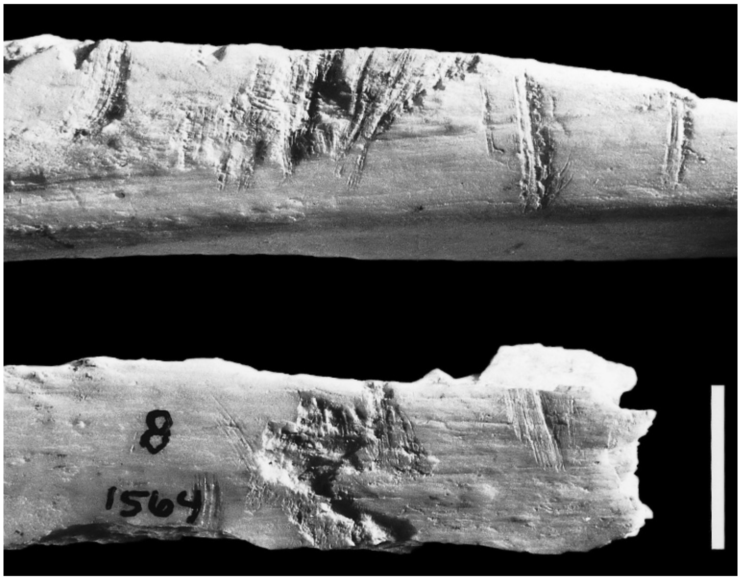


Figure 20.10 **Percussion pits associated with percussion striae on long bone shaft fragments.** The co-occurrence of hammerstone and anvil striae with these pits is good evidence of human involvement in the processing of these bones. Bar: 1 cm. From White (1992).

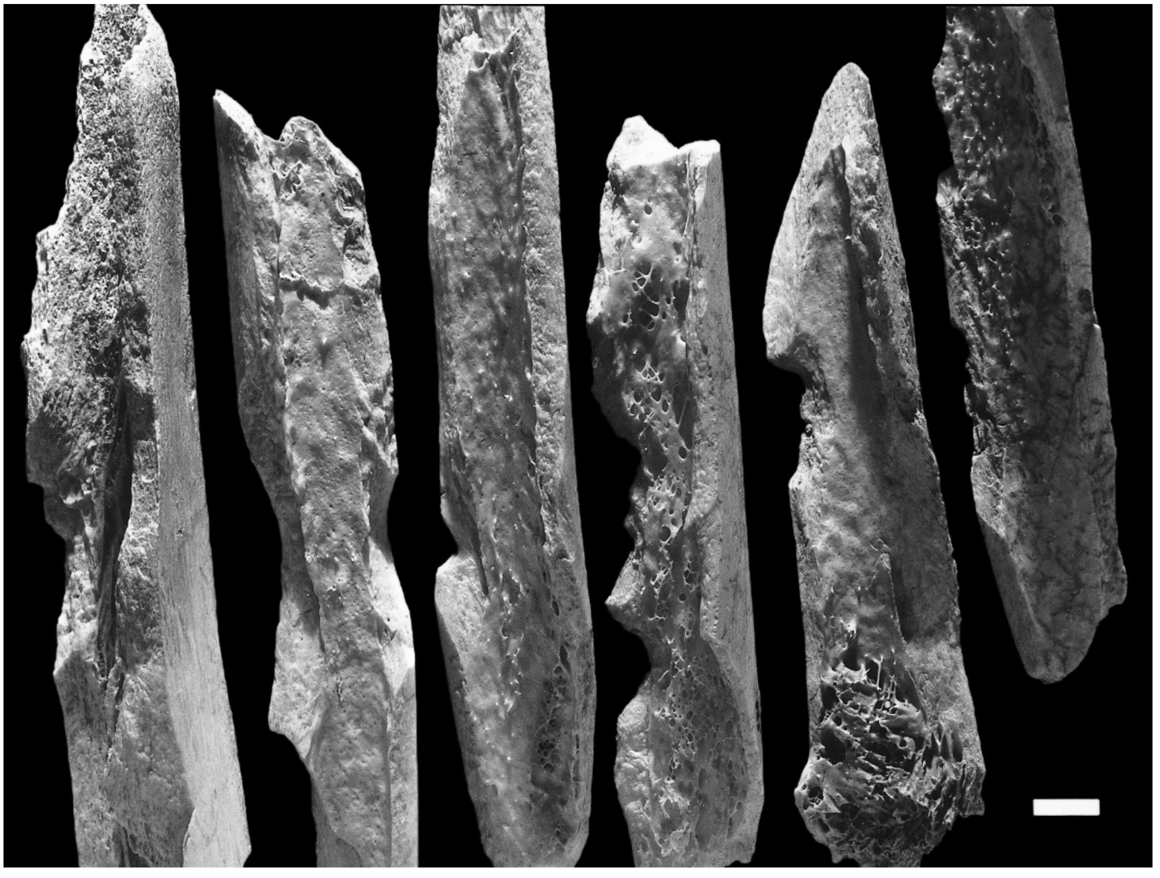


Figure 20.11 **Inner conchoidal scars.** These were formed when these femoral specimens were fractured for their marrow. Bar: 1 cm. From White (1992).

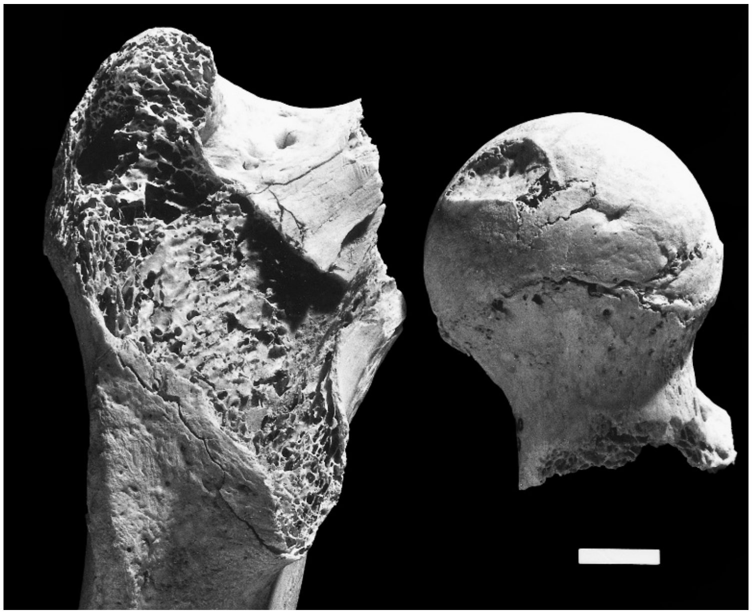


Figure 20.12 **Crushing damage.** When spongy bone is crushed by force, cortex on the adjacent areas is pushed into the crushed area, as in these femoral specimens. Note also the disarticulation cut marks on the femoral neck. Bar: 1 cm. From White (1992).

Figure 20.13 **Peeling damage.** Peeling on a juvenile's proximal ulna (top) and an adult's rib (bottom). Bar: 1 cm. From White (1992).

20.4.3 Projectiles

The previous examples of bone modification have been selected from archaeological contexts, but because fresh bone interacts with foreign objects in the same way, the behavioral deductions based on such modifications also largely apply in the modern forensic realm. In this realm, matching bone modifications found on victims of knives and other tools to the tools themselves is sometimes possible and important. High-speed projectiles such as arrows have been modifying human skeletal remains for thousands of years (Figure 20.14). In the modern forensic context, projectiles are most often metal, in the form of bullets of various caliber, or shrapnel (Figure 20.15). The analysis of entry versus exit damage to osteological remains is often critical in forensic investigations. In addition to this bone modification evidence, the radiographic discovery of foreign metal or other objects in skeletal remains often constitutes an additional critical dimension of forensic analysis, and X-radiography of skeletal remains in forensic cases is routine.

Figure 20.14 **Projectile point embedded in the ventral surface of a human sternum.** No bony reaction is seen, indicating that the event was perimortem, cause of death unknown. Prehistoric California. Natural size.

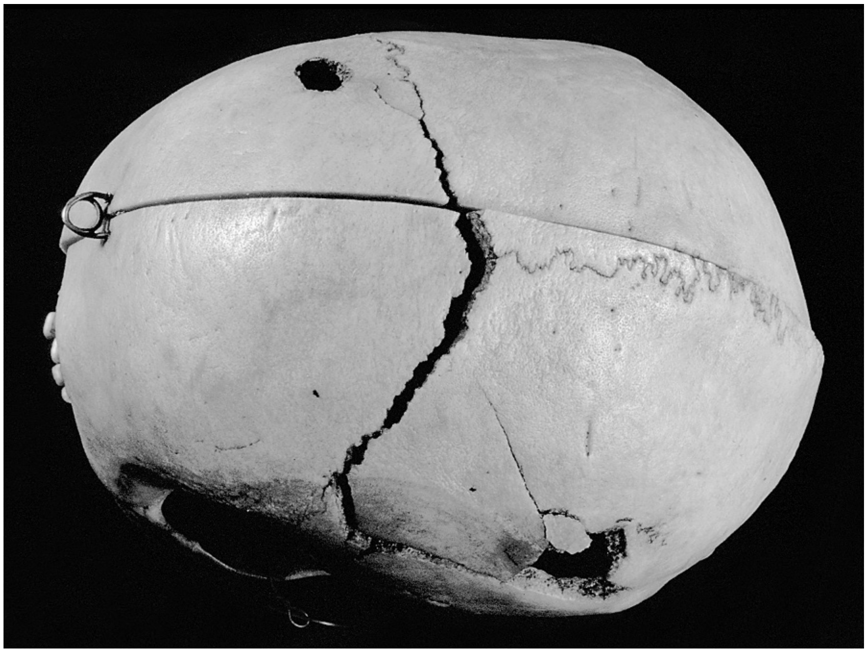


Figure 20.15 **Bullet entry and exit wounds**. From a modern human homicide victim. Cause of death known from autopsy records. Modern Cleveland. Approximately three-fifths natural size.

Suggested Further Readings

Binford, L. R. (1981) *Bones: Ancient men and modern myths.* New York, NY: Academic Press. 320 pp.

An important book about faunal remains in archaeological contexts.

Bonnichsen, R. and Sorg, M. H. (Eds.) (1989) *Bone modification.* Orono, ME: Center for the Study of the First Americans. 535 pp.

This publication of the results of the First International Conference of Bone Modification is a definitive sourcebook on the subject, with papers on topics related to bone modification in a wide range of settings.

Brain, C. K. (1981) *The hunters or the hunted? An introduction to African cave taphonomy.* Chicago, IL: University of Chicago Press. 365 pp.

A classic taphonomic study of bone assemblages from *Australopithecus*-bearing deposits in South Africa.

Connor, M. A. (2007) *Forensic methods: Excavation for the archaeologist and investigator.* Walnut Creek, CA: Altamira Press. 272 pp.

A good introduction to many of the techniques used in forensic anthropology. Includes legal issues and crime scene reconstruction.

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